

Abb. 2: Kokardendolomit im Anschliff.

Nach mechanischer Aufbereitung wurden nun die handverlesenen Komponenten der Kokarden (Kern, dunkle Dolomitmatrix, helle Dolomitsäume) einer vielseitigen geochemischen Analytik unterzogen: AAS: Ca, Mg, Fe, Mn, Pb, Zn, Sr, K, Na; MCICP: Spuren- und SE-Elemente; LAICPMS: Sr-Isotopie; MCICPMS: C, O-Isotopie und Ionen-chromatographische nach Crash & Leach Aufschluß. Der Geländebefund deutet auf Spaltenfüllungen, die mitunter auch schräg zu Schichtlagerung verlaufen. Die Magnesitkerne der KD zeigen bei Haupt- und Spurenelementgehalten sowie REE Mustern keine signifikanten Unterschiede zu den redolomitisierten Spatmagnesiten der Lagerstätte, die bevorzugt entlang von Spaltrissen dolomitisiert wurden. REE Muster,  $\delta^{13}\text{C}$  und  $\delta^{18}\text{O}$ , Sr-Verhältnisse und Fluidanalytik der Dolomitsäume sind ähnlich denen der spätigen und z. T. in offenen Drusen gebildeten Roßzahndolomite. Wir sehen in den Kokardendolomiten hydrothermale Gangbildungen, die in der Mineralisationsabfolge sehr spät, ~zeitgleich mit Prozessen der Redolomitisierung und Roßzahnbildung erfolgte.

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### Mineralogical characterization of chromite ore deposits in eastern Khoy ophiolitic complexes (NW Iran): implication for the geodynamic evolution

AZIMZADEH, A.M.<sup>1</sup>, ZACCARINI, F.<sup>1</sup> & MOAYYED, M.<sup>2</sup>

<sup>1</sup>University of Leoben, Department of Applied Geosciences and Geophysics, 8700 Leoben, Austria;

<sup>2</sup>Department of Earth Sciences, University of Tabriz, Tabriz, Iran

Podiform chromitites hosted by Tethyan ophiolites are important from an economic point of view, since most of them represent a significant source for chromium recovery. The vast majority of the Tethyan chromitites are hosted in mantle tectonites and, according to their chemical composition, they can be classified as metallurgical chromite ores (40-54 wt%  $\text{Cr}_2\text{O}_3$ ; 12-18 wt%  $\text{Al}_2\text{O}_3$ ). These Cr-rich chromitites formed in the deep portion of the mantle and crystallized from a boninitic melt in a suprasubduction zone (SSZ). However, less occurrence of refractory chromite ores, or Al-rich chromitites (30-44 wt%  $\text{Cr}_2\text{O}_3$ ; 20-30 wt%  $\text{Al}_2\text{O}_3$ ) have been also described. The Al-rich chromitites occur higher in the ophiolite stratigraphy close to the Moho transition. They are generally associated with MORB-like, back-arc basalts and generated by decompression melting at seafloor spreading centers.

More than 70 chromite deposits have been described in the Tethyan ophiolites of Iran. Therefore, this country is considered one of the important chromium producers in the world. However the Iranian chromitites has been poorly investigated. This contribution focuses in on the magmatic significance of chromite composition in podiform chromitites, never studied before, related with the Khoy ophiolite. The Khoy ophiolite, located few kilometers from the homonymous city, with an area of more than 700 km<sup>2</sup>, is one of the largest ophiolite of Iran. It is considered a fragment of the oceanic lithosphere formed in the Mesozoic Neo-Tethys (HASSANIPAK & GHAZI 2000). It consists of a mantle sequence composed of dunite and harzburgite partially to totally serpentinized accompanied by minor chromitites. The mantle sequence is overlay by the following crustal rocks: cumulate gabbros, diorite, pillow and massive basalts, covered by a pelagic sedimentary sequence including umber and radiolarian chert. Two different complexes have been recognized in the Khoy area: the Western and Eastern Khoy Ophiolitic complexes, respectively. The first is Late Cretaceous in age, whereas the age of the second is Early Jurassic to Early Cretaceous. The evolution of the Khoy ophiolitic complexes is still matter of debate. HASSANIPAK & GHAZI (2000), based on geochemical data, proposed that the Khoy ophiolites were originated along a MOR. Other authors demonstrated that the Eastern Khoy Ophiolitic Complex was indeed a metamorphosed suprasubduction-related complex progressively thickened throughout the trench. It possibly formed in a slow-spreading back-arc basin, which was obducted over the island arc tholeiitic and calcalkaline rocks of the adjacent arc system during the Late Cretaceous (MONSEF et al. 2010 and references therein). We have investigated 3 samples (MM1, M365 and MA2) collected

in partially serpentinized peridotite from the Eastern Khoy Ophiolite. Reflected light microscope investigation reveals that only chromitites from MM1 are massive (<10 % interstitial silicate) interrupted by cracks and pull-a-part fractures. Chromitites from M365 and MA2 consist of high grade dissemination with more than the 50 % of chromite in a silicate matrix mainly composed of altered silicates, showing an orbicular or leopard texture. This texture is well preserved in MA2 chromitites, with orbicular size up to 3 mm. In samples M365 the orbicular texture is partially obliterated by the presence of strongly brecciated and fractured zone. Primary chromite composition has been obtained in the preserved core of spinel grains. The averages, calculated on about 500 analyses, of major oxides (wt.%) in the unaltered cores of chromite grains are reported in the following: MM1 = Cr<sub>2</sub>O<sub>3</sub> (40.8), Al<sub>2</sub>O<sub>3</sub> (26.12), MgO (13.45), FeO (14.6), M365 = Cr<sub>2</sub>O<sub>3</sub> (35.01), Al<sub>2</sub>O<sub>3</sub> (31.54), MgO (14.6), FeO (13.6) and MA2 = Cr<sub>2</sub>O<sub>3</sub> (33.46), Al<sub>2</sub>O<sub>3</sub> (32.52), MgO (14.9), FeO (13.19). The calculated amount of Fe<sub>2</sub>O<sub>3</sub> is lower than 1.8 wt% and the TiO<sub>2</sub> content is less than 0.2 wt%. Our results indicates that the chromite compositions varies little from one locality to the other, and all the analyzed chromitites can be classified as refractory or Al-rich. This suggests that they do not precipitate from a boninitic melt related with a SSZ, in a compressive geodynamic setting. More likely, they crystallized from a normal MOR or back-arc type melt in an extensional regime.

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### Modelling of geological fluids in the H<sub>2</sub>O-NaCl-KCl fluid system

BAKKER, R.J.

University of Leoben, Department of Applied Geosciences and Geophysics, Mineralogy and Petrology, Peter-Tunner-Strasse 5, 8700 Leoben, Austria

A H<sub>2</sub>O-NaCl-KCl-rich fluid occurs occasionally in fluid inclusions in a variety of geological environments. The properties of this fluid provide information about the conditions of entrapment, and thereby, conditions that have affected the rock. This fluid system has already been studied extensively and modelled according to thermodynamic principles and purely empirical „best-fit“ analyses (STERNER et al. 1988, 1992). However, the provided models are internally inconsistent and are partly not reproducing the available experimental data. Therefore, new models are developed to reproduce the properties of the H<sub>2</sub>O-NaCl-KCl fluid system, especially the liquidus at variable pressures (the solid+liquid+vapour surface, i.e. HLV), and at constant pressures (the solid+liquid surface, i.e. HL).

The HLV surface reaches pressures up to 39 MPa (NaCl-H<sub>2</sub>O-rich fluids), and the behaviour of fluid inclusions during microthermometric experiments, i.e. the dissolution of a halite crystal and a sylvite crystal in the presence of a vapour bubble, is defined according to the thermodynamic properties at this surface. The HLV surface is modelled in this study according to purely empirical „best-fit“ polynomial equations, which relate temperature, pressure and composition (Fig. 1). The HL surfaces, at constant pressures, are modelled according to thermodynamic principles, i.e. the equality of chemical potentials of components (NaCl and KCl) in each phase at equilibrium. The HL-equations can be applied in the range of 300 to 1000 °C, and pressures from 30 to 250 MPa, which is defined by the experimental data that is used to develop this model. The new models are included in the software package FLUIDS (BAKKER 2003), to be able to apply directly the mathematical functions in fluid inclusion studies and in general fluid properties investigations. The computer program AqSoWNK has been developed in REALBasic (© Real Software, Inc.) with a graphical user interface. The program is composed of two main applications: 1. salinity determination from known dissolution temperatures, at variable pressure (HLV) and constant pressures (HL); 2. dissolution temperature determination from known salinities at variable pressures (HLV) and constant pressures (HL). In addition, the program reveals thermodynamic properties, including the excess Gibbs energy and chemical potentials at selected conditions.

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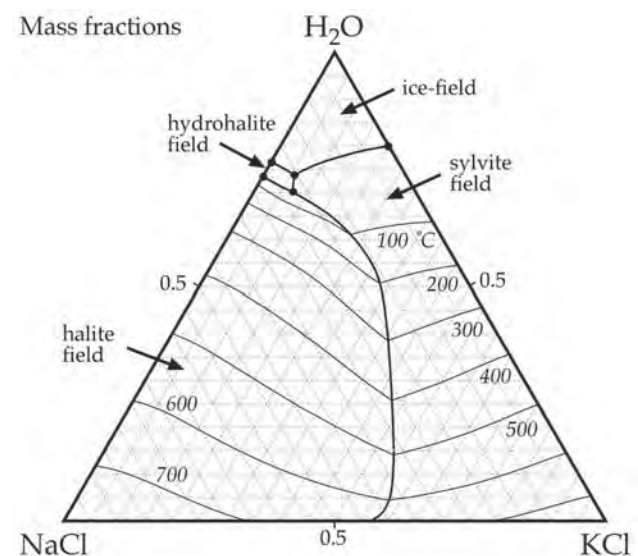


Fig. 1: Isotherms in the HLV surface in a H<sub>2</sub>O-NaCl-KCl compositional diagram.